THE RAMAN LASER SPECTROMETER (RLS) ON THE EXOMARS 2018 ROVER MISSION. F. Rull[1], S. Maurice[2], E. Diaz[3], C. Tato[4], A. Pacros[5] and the RLS Team, [1]Unidad Asociada CSIC-CAB, Universidad de Valladolid, Boecillo, Spain, [2]Institut de Recherche en Astrophysique et Planétologie, Toulouse, France, [3]Instituto Nacional de Técnica Aeroespacial (INTA), Torrejón de Ardoz, Spain, [4]SENER, Madrid, Spain, [5]ESA-ESTEC, Noordwijk, The Netherlands (rull@fmc.uva.es; sylvestre.maurice@cesr.fr).

Context. The main science objectives of the ESA-led 2018 ExoMars rover mission are: to search for signs of past and present life on Mars; to characterize the water/geochemical environment as a function of depth in the shallow subsurface; to study the surface environment and identify hazards to future human missions; to investigate the planet's subsurface to better understand the evolution and habitability of Mars [1, 2].

To address these exobiological and geochemical issues, the project office has selected a Raman-based investigation (Raman Laser Spectrometer – RLS) led by F. Rull, as part of an analytical suite of four instruments in the body of the vehicle. The Rover subsurface sampling device will drill down to maximum 2 m. The sample will be crushed into a fine powder. By means of a dosing station the powder will then be presented to RLS and other instruments [1, 2].

Raman Science objectives. Raman spectroscopy is a non-destructive analytical tool to learn about vibrational, rotational, and other low-frequency modes in a system. It relies on inelastic scattering of monochromatic light from a laser. The laser light interacts with molecular vibrations, resulting in the energy of the laser photons being shifted up or down. The shift in energy gives information about the phonon modes in the system. On a geochemical target, Raman spectroscopy is a very powerful tool to detect unambiguously C-C, C-H bonds, carbonates, sulfates, hydrated minerals and most generally organics [3]. See figure 1.

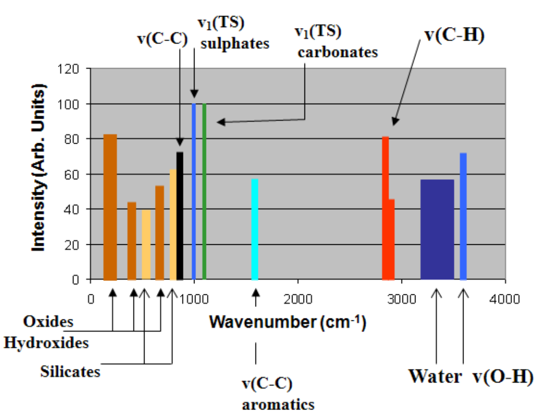

Figure 1: Raman spectral shifts for exobiological and geo-chemical targets of interest.

The RLS team has defined two areas of investigation: 1/ the search for past or present life, which is related to the direct identification of organic compounds, and the identification of minerals products as indicators of biological activity; 2/ the description of water-related processes, which is associated to the identification of minerals phases produced by fluid-rock interactions, and the characterization of igneous minerals and their alteration products.

RLS can identify the elemental composition and structure of a phase at the mineral grain scale. This capability provides a definitive characterization of a target material. Hence, RLS can be used as a "rapid target evaluation" for tactical decisions during the mission.

Instrument design. The RLS team has chosen a continuous excitation wavelength at 532 nm. This laser will be able to provide a total of 400 individual sets of measurement cycles (10 min max. each). The laser spot size will be around 50 µm on the target, to be compatible with the other analytical tools of the mission. This target size produces an irradiance on the target between 0.8 and 1.2 kW/cm^2. The upper limit is fixed to remain below the threshold of powder grain thermal damage mainly in oxides and hydroxides. The goal of the spectrometer is to cover the spectral shift from ~150 to 3800 cm^{-1} to capture the range of fundamental vibrations of rock forming minerals, oxyanionic anions, functional groups of organic species, H_2O and OH vibrations in hydrates. The Raman spectral resolution goal is ~6 cm^{-1} in the fingerprint spectral region below 2000 cm^{-1} and higher above this limit.

Because of implementation issues (thermal or planetary protection issues) within the rover analytical lab, the RLS instrument consists of three independent units connected via electrical and optical harnesses. The laser is in the Instrument Control and Excitation Unit (ICEU). Its collimated beam is conveyed to the Internal Optical Head (iOH), where it is focused on the target. This unit must incorporate a mechanism to adjust the optical focus because of irregularities of the target plan. The Raman signal is collected through the same fore optics, the excitation wavelength is filtered out, and the signal is transmitted to the Spectrometer Unit (SPU) for dispersion and capture on a 2D CCD. Figure 2 shows how the sub-units are implemented in the rover Analytical Laboratory Drawer (ALD). The target is within an ultra-clean zone, not in physical contact with RLS. Figure 3 shows a functional diagram of RLS. A few details are given hereafter.

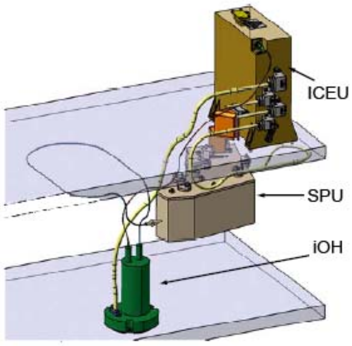

Figure 2. RLS implementation within the ALD. The total mass of the instrument is ~2.5 kg.

- *Spectrometer Unit*. The dispersion of Raman light is obtained by transmission using a holographic grating. The Raman spectrum is registered on a 2048x512 pixel CCD. This CCD requires operating at cold temperature maintained by means of a TEC cooling device.
- *Control and Excitation Unit.* It includes the DC/DC power converters and the data processing capability (µcontroller, RAM, clock and CANBus). Its role is also to capture the RLS health parameters and to run the thermal management. To support other functionalities of the instrument, it comprises the laser with two redundant excitation outputs, the CCD FEE electronics, and the autofocus driver.
- *Optical head*. The range of focus is ±1 mm simultaneously for the excitation and the collection. The signal collection is based on a simple aspheric collimator. Mini-connectors are used to connect the fibers.

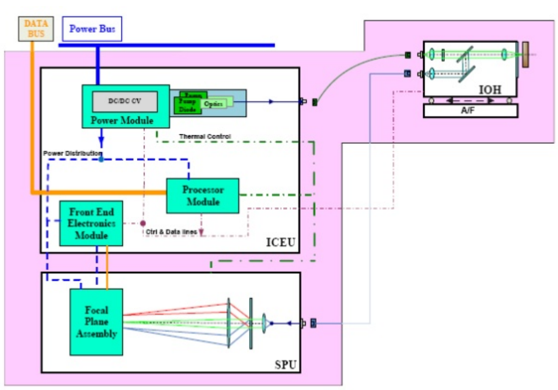

Figure 3. Instrument functional diagram

Operation Modes. There shall be two operational modes: an automatic scanning and a smart scanning. The mode selection will be performed by spacecraft commands from ground. During automatic scanning, the rover shall place the target following a preconfigured sequence of movements in front of RLS optical head. RLS shall take at least 20 shots per sample at regularly spaced spots on the target. During smart scanning, MicrOmega IR images shall be processed by the rover to determine target of interest on axis. The rover shall place the target of interest RLS optical head. In case no target of interest is found, preconfigured sequence of movements shall be performed.

Instrument status. The instrument is being developed, pending its Phase-C to start early 2011. A laboratory prototype already exists at INTA in Madrid. It will be in the form of a fully functional breadboard by the end of Phase-B

In parallel, a powder analysis simulator has been developed at the Unidad Asociada UVA-CSIC-CAB in Valladolid (Fig. 4). The purpose of this experiment is to consolidate the instrument baseline (irradiance levels, autofocus and data processing algorithms), to improve the Raman technique on complex geological targets, to define and rehearse the operation modes, to refine our coordination with other instruments, namely MicrOmega and XRD.

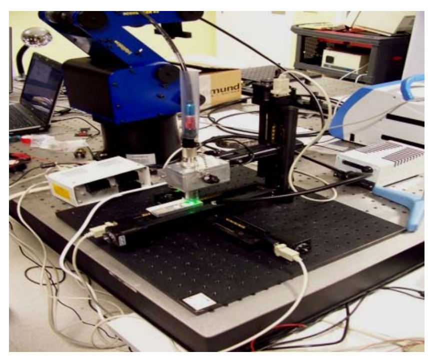

Figure 4. Raman powder analysis simulator

RLS science team: The development of the RLS instrument is a large team effort. The consortium is led by the science team, in Spain: F. Rull (PI) and J. M. Frias; in France: S. Maurice (deputy-PI) and L. d'Uston; in Germany: E. Jessberger and J. Popp; in United Kingdom: I. Hutchinson and H. Edwards, in the Netherlands: G. Davies; in the United States: S. Sharma and A. Wang.

References. [1] Vago et al. (2006) European Planetary Science Congress 2006, Berlin, p76. [2] The ExoMars Rover Instrument Suite/Raman Spectrometer on exploration.esa.int. [3] Rull et al. (2009) Geo. and Cosmo. Acta Supplement, vol 73, p. A1133.